Prospects for B_s Mixing for CDF II

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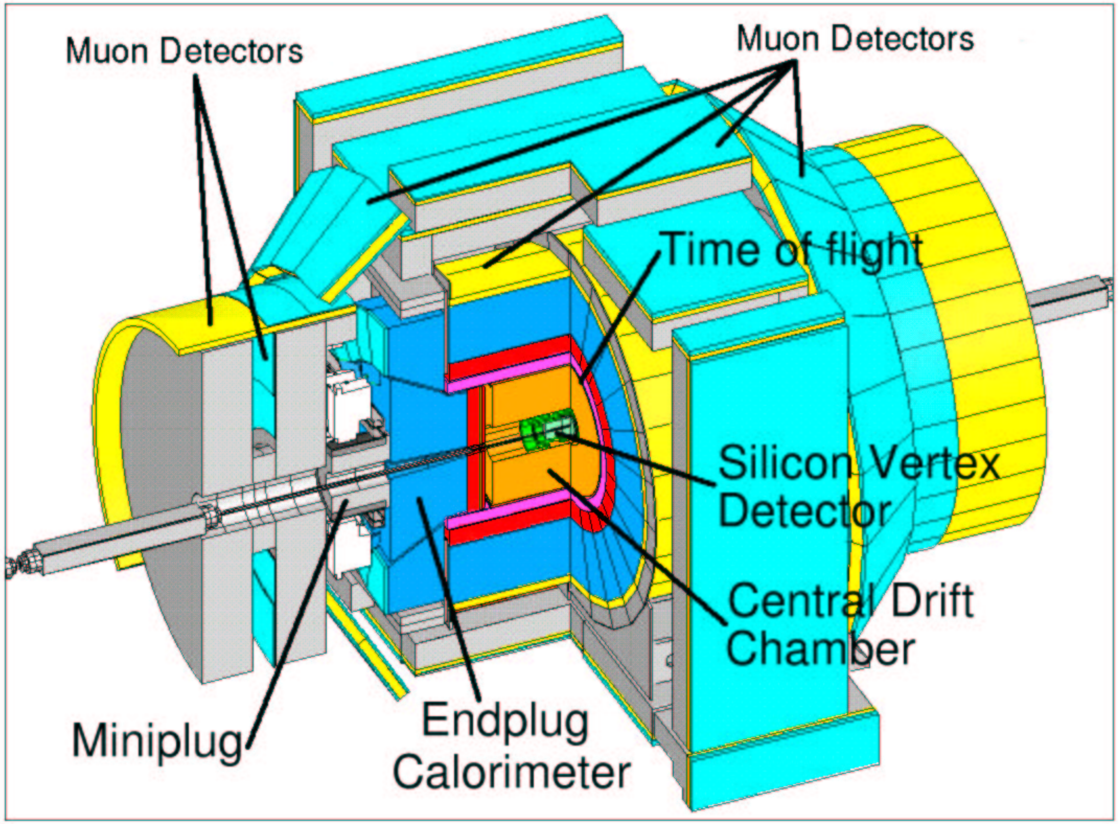
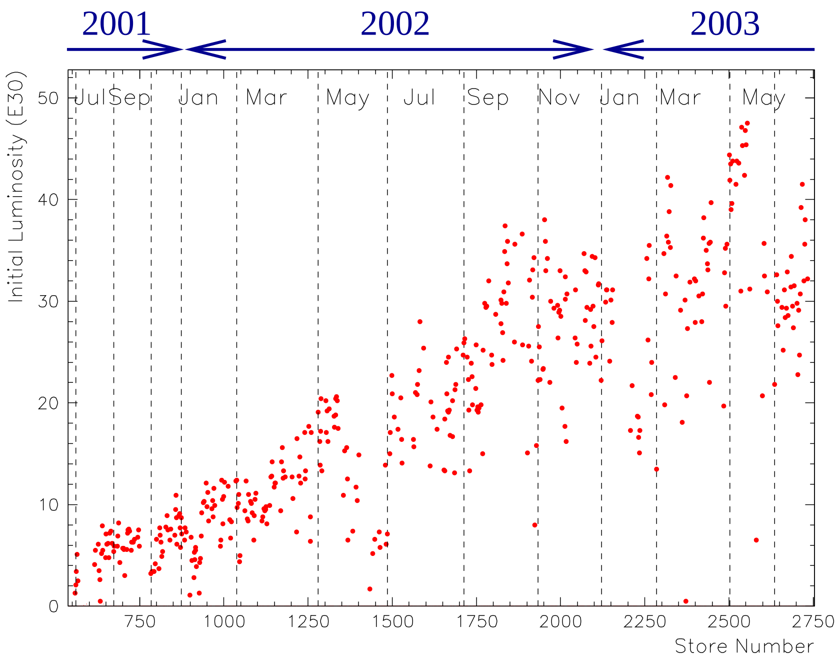
CDF II Detector

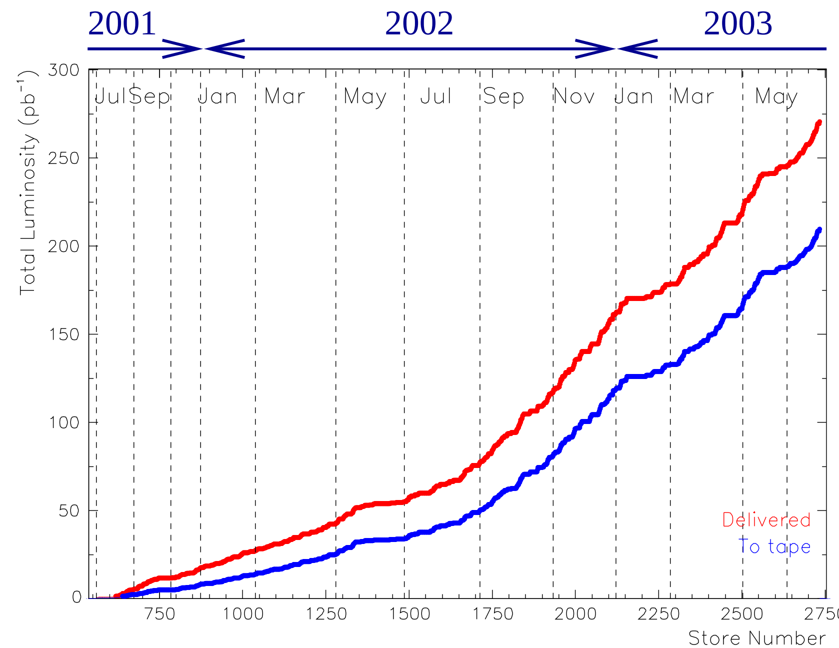


New Detector components:

- Tracking System
  - 3D Silicon Vertex Detector ($|\eta| \leq 2$)
  - Drift Chamber
- Time of Flight (particle ID)
- Plug & Forward Calorimeters
- DAQ & Trigger systems (Online Silicon Vertex Tracker: trigger on displaced vertices)

Luminosity and Data Taking





Accelerator Performance:

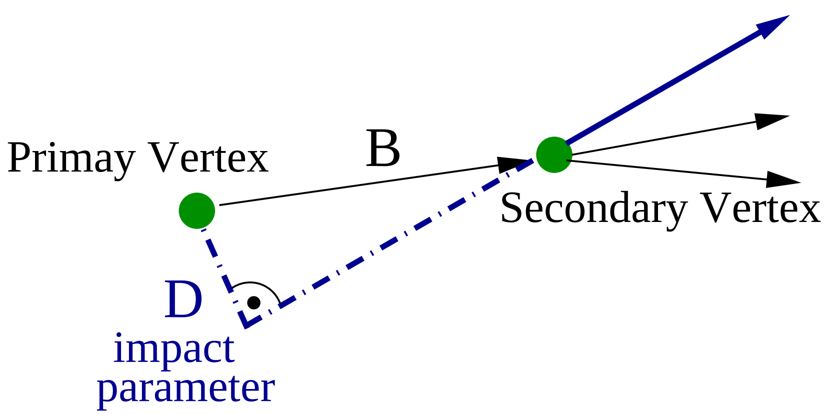
- record: $4.7 \times 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- still below expectations by $\times$ 2
- improving slowly
- 4-7 pb^{-1} per week

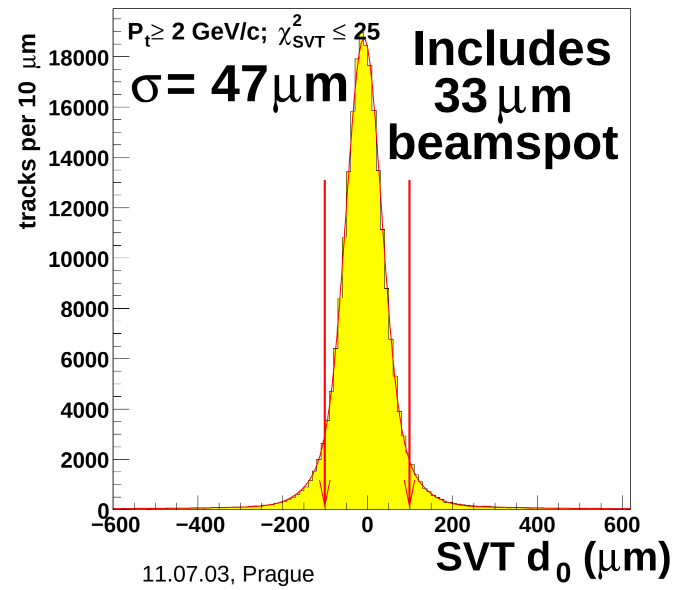
Data Taking:

- 270 pb^{-1} taken (tape: 210 pb^{-1})
- $\geq$ 140 pb^{-1} good data (with all important systems on)
- Data taking efficiency $\approx$ 80-90%

B Triggers

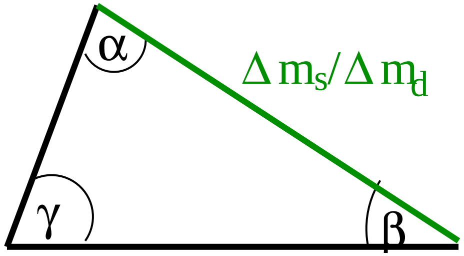
Conventional	New in CDF - For the first time in hadronic environment	
Di-Muon (J/Ψ)	**Displaced track + lepton e, μ**	**Two track**
• $P_t(\mu) \geq 1.5$ GeV	• D(track) $\geq 100\ \mu$m • P_t(lepton)$\geq$ 4 GeV	• D(track) $\geq 120\ \mu$m • P_t(track) ≥ 2 GeV
J/Ψ modes down to low P_t	**Semileptonic modes**	**Fully hadronic modes**
• CP violation • Masses, lifetimes • Quarkonia, rare decays	• High statistics lifetime • Sample for tagging studies, mixing	• B_s mixing • CP asymmetry in 2-body charmless decays



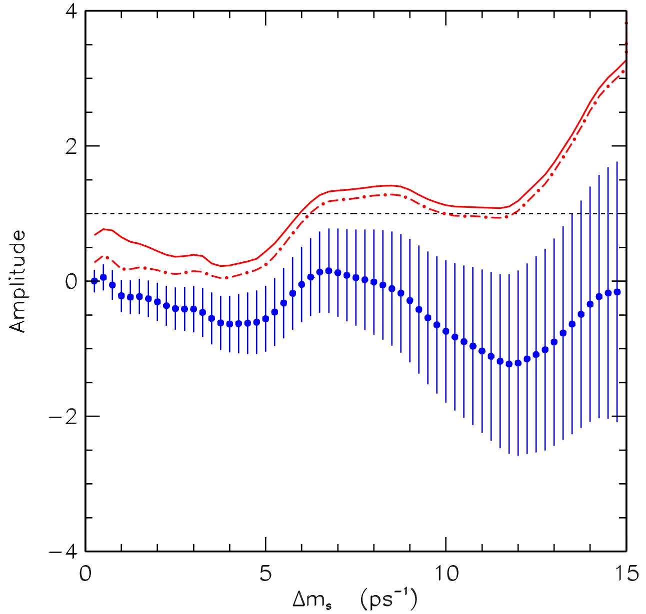


Ingredients for B_s^0 mixing

$$A_{mix}(t) = \frac{N_{mix}(t) - N_{unmix}(t)}{N_{mix}(t) + N_{unmix}(t)} = -D * cos(\Delta m_s t)$$



CDF Run I limit: $\Delta m_s \geq 5.8\ \mathrm{ps}^{-1}$



Current world average limit:

$\Delta m_s \geq 14.4\ \mathrm{ps}^{-1}$

- Reconstruct final state
  - hadronic trigger:

    $B_s \to D_s \pi\ (D_s \to \phi\pi, \phi \to KK)$

    $B_s \to D_s \pi\pi\pi$
  - semileptonic trigger:

    $B_s \to D_s l \nu X\ (D_s \to \phi\pi, \phi \to KK)$
- Identify the flavour of B_s at production:

  $\to$ B-flavour tagging

Significance of x_s measurement

$$\Delta_{x_s} \approx \sqrt{N\epsilon D^2} e^{-(x_s \sigma_{c\tau}/\tau)^2/2} \sqrt{\frac{S}{S+B}}$$

N: event yield (includes trigger, detector and reconstruction efficiency)

ϵD^2 from tagging

Efficiency: $\epsilon = \frac{N_w + N_r}{N}$

Dilution: $D = 1 - 2\frac{N_w}{N_w + N_r}$

$x_s = \Delta m_s / \tau(B_s)$

$c\tau = \frac{L_{xy}}{\gamma\beta}; \gamma\beta = \frac{p_T(B)}{M(B)}$

$$\sigma_{c\tau} = \left(\frac{\sigma_{L_{xy}}}{\gamma\beta}\right) + \left(\frac{\sigma_{\gamma\beta}}{\gamma\beta}\right) * c\tau$$

60 fs (SVX II)

45 fs (SVX II + Layer00)

15 % (semileptonic)

negligible (0.5 %) for fully reconstructed states

S:B Signal to background ratio

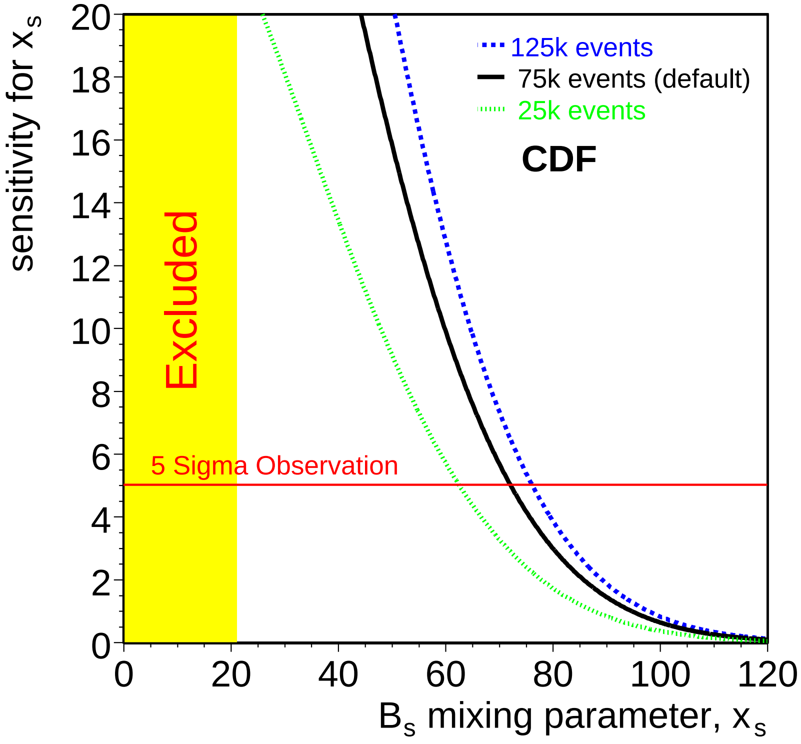
Yellow Book Predictions

Some estimates from the Yellow book:

- need about 100 pb^{-1} to cover Standard Model prediction
- measure B_s mixing with the first month of data
- easy and quick analysis

That was the plan ...

... but event yield lower than expected,
tagging not yet as good as expected.



$$B_s \to D_s(3)\pi$$

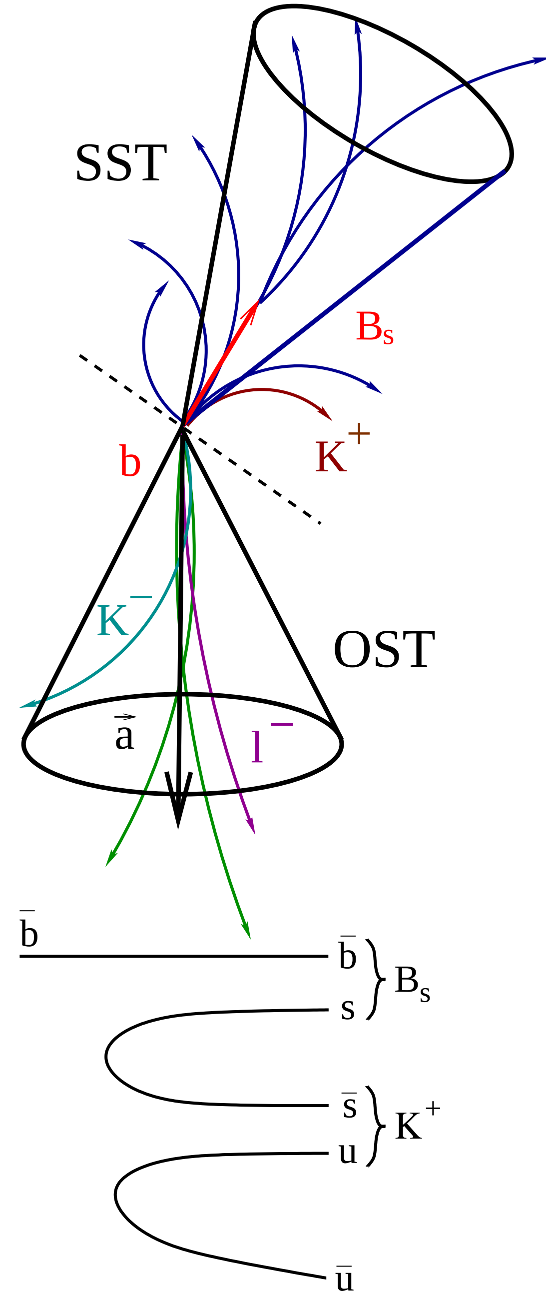
B_s Flavour Tagging

Opposite Side Tagging:

- Jet-Charge-Tagging:
  sign of the weighted average charge of opposite B-Jet

$$Q_{jet} = \frac{\sum_i q_i(\vec{p_i}\vec{a_i})}{\sum_i \vec{p_i}\vec{a_i}}$$

- Soft-Lepton-Tagging:
  identify soft lepton (e, μ) from semileptonic decay of opposite B: $b \to l^- X$ (BR $\approx 20\%$),
  Dilution due to $\bar{b} \to \bar{c} \to l^- X$ and oscillation
- Kaon-Tagging:
  due to b→c→s it is more likely that a $\bar{B}$ meson contains a K^- than a K^+ in the final state



Same Side Tagging:

- B_s is likely to be accompagnied close by a K^+

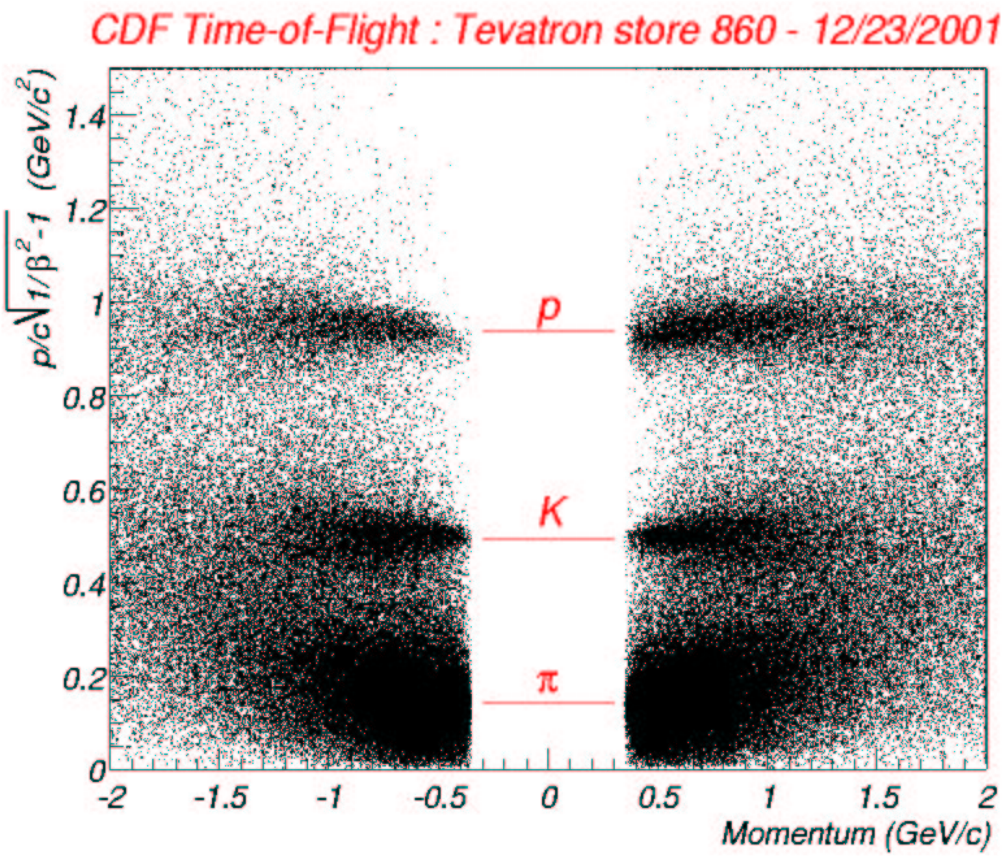
B_s Flavour Tagging (II)

expected performance:

Method	ϵD^2
JQT	3.0%
SLT	1.7%
OSK	2.4%
SST	4.2%
Total	11.3%

B_s flavour tagging heavily relies on Kaon identification

$\rightarrow$ Time Of Flight



Detector functions very well

Occupancy is somewhat higher than expected

Work on improving reconstruction ongoing

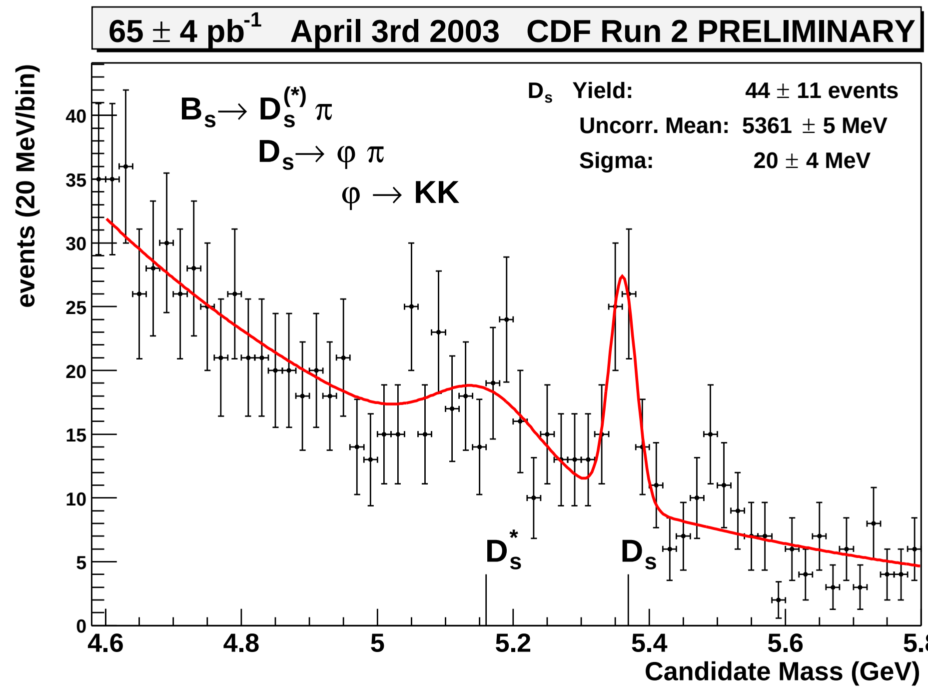
B_s Event Yield

Golden Mode:

$B_s \to D_s\pi$

$D_s \to \phi\pi$

$\phi \to KK$



N(B_s) = 44 ± 11

Increase rate by adding additional modes:

- $B_s \to D_s\pi\pi\pi, D^0K\pi$
- $D_s \to K^*K, \pi\pi\pi, K_sK$

Need about O(10^3) events to observe Standard Model B_s oscillation at 5 σ.

May take a while ...

Efficiency Studies

- develop realistic MC
- determine relative efficiencies for kinematically similar processes with well known fragmentation/branching ratio:

$$B_d \to D^{\pm}\pi^{\mp} \qquad\qquad B_u^{\pm} \to D^0\pi^{\pm}$$
$$D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm} \qquad\qquad D^0 \to K^{\pm}\pi^{\mp}$$

$$\frac{N_{B_d}}{N_{B_u}} = \frac{f_d}{f_u}\frac{\epsilon_{B_d}}{\epsilon_{B_u}}\frac{Br(B_d \to D\pi)Br(D \to K\pi\pi)}{Br(B_u \to D^0\pi)Br(D^0 \to K\pi)}$$

- advantage: systematics in trigger and reconstruction efficiencies canncel
- compare relative yield N_{B_d}/N_{B_u} on MC/data:

MC: $\frac{N_{B_d}}{N_{B_u}} = 1.18 \pm 0.21$

data: $\frac{N_{B_d}}{N_{B_u}} = 1.04 \pm 0.13$

$\to$ MC describes well data!

Relative B_s Yield

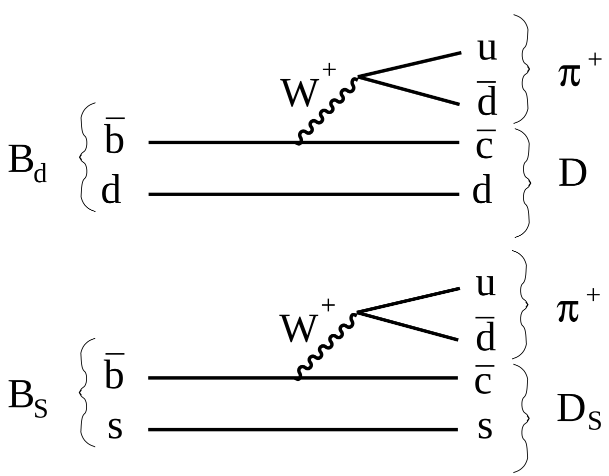
reconstruction efficiencies from MC — branching ration from PDG

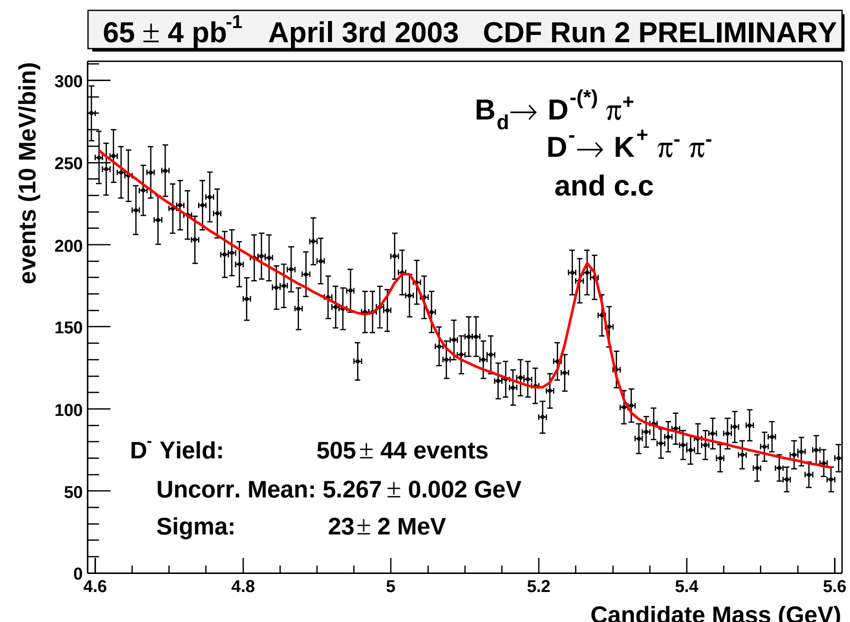
$$\frac{N_{B_s}}{N_{B_d}} = \frac{f_s}{f_d}\,\frac{\epsilon_{B_s}}{\epsilon_{B_d}}\,\frac{Br(B_s \to D_s^- \pi^+)}{Br(B_d \to D^- \pi^+)}\,\frac{Br(D_s^- \to \phi\pi^+)Br(\phi \to K^- K)^+}{Br(D^- \to K^- \pi^+ \pi^+)}$$

$$\frac{f_s}{f_d}\frac{Br(B_s \to D_s \pi)}{Br(B_d \to D\pi)} = 0.42 \pm 0.11(stat.) \pm 0.11(BR) \pm 0.07(syst.)$$

with $\frac{f_d}{f_s} = 3.91 \pm 0.52$ (from PDG):

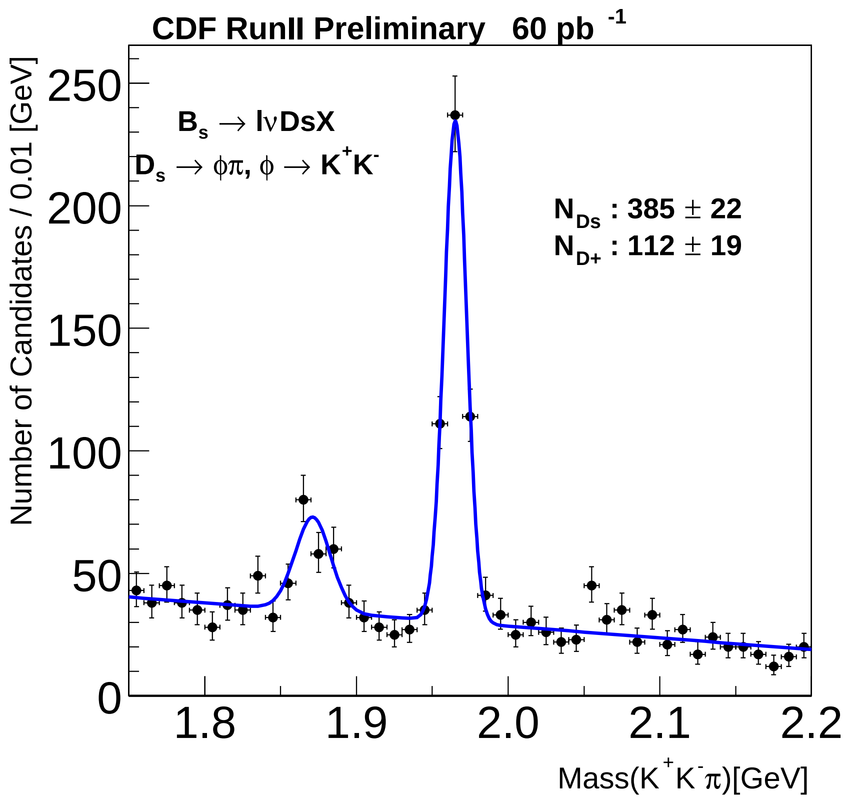
$$\frac{Br(B_s \to D_s \pi)}{Br(B_d \to D\pi)} = 1.64 \pm 0.43(stat.) \pm 0.43(BR) \pm 0.27(syst.) \pm 0.22(\frac{f_d}{f_s})$$





Semileptonic Trigger: $B_s^0 \to D_s l \nu X$

- clean and large sample
- Yield/Lumi $\approx 3\times$ Run I
- S/N $\approx 2\times$ Run I



Proper Time Resolution:

$$ct = \frac{L_T(B_s)M(B_s)}{p_T(B_s)} = \frac{L_T(B_s)M(B_s)}{p_T(lD_s)}K$$

$$K = \frac{p_T(lD_s)}{p_T(B_s)}$$

$$\sigma_t = \sigma_{t_0} + t * \frac{\sigma(K)}{K}$$

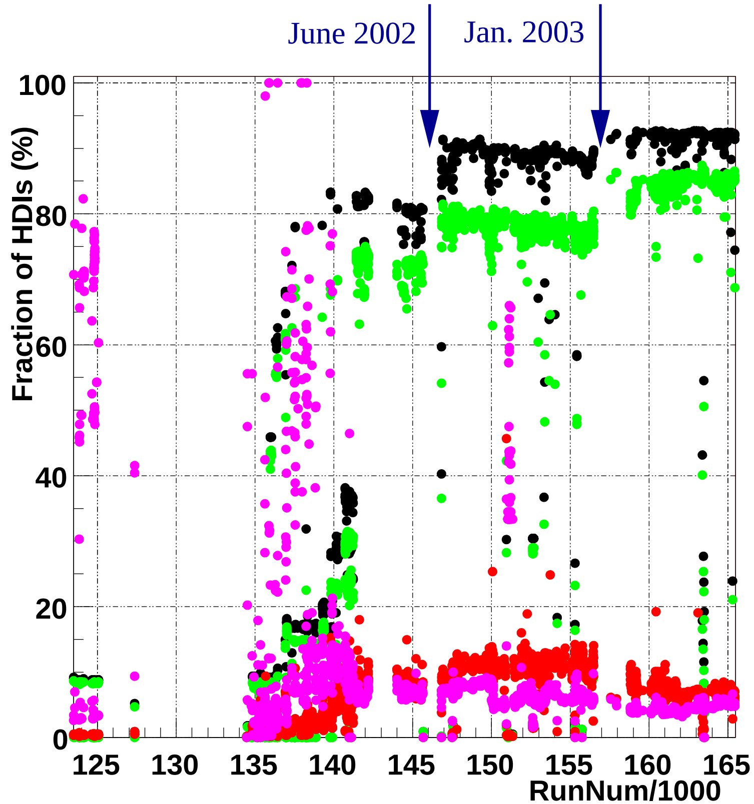
$$\frac{\sigma(K)}{K} \approx 15\% \text{ (taken from MC)}$$

limited B_s mixing sensitivity, back-up sample

B Yield Improvement

- improvements in silicon coverage
  - $\rightarrow$ improves trigger efficiency
    SVT-require 4 of 5 layers (before 4/4)
  - $\rightarrow$ improves reconstruction efficiency

- Tevatron luminosity is below design
  - $\rightarrow$ there is available trigger bandwidth
  - Dynamic prescaling
  - Confirm track D_0 in Level 3 trigger
  - Tighten fast track processor requirements



- 92.5 % of silicon is running
- 85.0 % is getting good data

Expect a factor of 2-4 improvements in yield.
However, as luminosity increases, this will have to be scaled back.

Conclusion

- machine and detector had startup problems, more than a year for 100 pb^{-1}
- data taking/trigger/silicon efficiency lower than expected
  $\rightarrow$ will improve
- tagging at the moment not as good as expected (especially for Kaons)
  $\rightarrow$ will improve
- $B_s \rightarrow D_s \pi$ events have been reconstructed
- a realistic MC has been developed which reproduces all efficiencies
  $\rightarrow$ production rates are well understood
- wait for new data, need at least 200 pb^{-1} “good data” for covering Standard Model predictions
- B_s mixing will be a very tough analysis,
  but SM range will be covered before LHC !